World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:11, No:12, 2017

Sustainability Assessment of a Deconstructed Residential House

Atiq U. Zaman, Juliet Arnott

Open Science Index, Civil and Environmental Engineering Vol:11, No:12, 2017 waset.org/Publication/10008297

Abstract**—**This paper analyses the various benefits and barriers of residential deconstruction in the context of environmental performance and circular economy based on a case study project in Christchurch, New Zealand. The case study project "Whole House Deconstruction" which aimed, firstly, to harvest materials from a residential house, secondly, to produce new products using the recovered materials, and thirdly, to organize an exhibition for the local public to promote awareness on resource conservation and sustainable deconstruction practices. Through a systematic deconstruction process, the project recovered around 12 tonnes of various construction materials, most of which would otherwise be disposed of to landfill in the traditional demolition approach. It is estimated that the deconstruction of a similar residential house could potentially prevent around 27,029 kg of carbon emission to the atmosphere by recovering and reusing the building materials. In addition, the project involved local designers to produce 400 artefacts using the recovered materials and to exhibit them to accelerate public awareness. The findings from this study suggest that the deconstruction project has significant environmental benefits, as well as social benefits by involving the local community and unemployed youth as a part of their professional skills development opportunities. However, the project faced a number of economic and institutional challenges. The study concludes that with proper economic models and appropriate institutional support a significant amount of construction and demolition waste can be reduced through a systematic deconstruction process. Traditionally, the greatest benefits from such projects are often ignored and remain unreported to wider audiences as most of the external and environmental costs have not been considered in the traditional linear economy.

Keywords**—**Circular economy, construction and demolition waste, resource recovery, systematic deconstruction, sustainable waste management.

I. Introduction

THE consumption of natural resources has increased significantly over the past. In fact, the extraction rates of minerals, ores, biomass and fossil fuels tripled globally during 1970-2010 [1]. The circulation of global primary materials through trade has grown at an ever-increasing rate over the past four decades and around 10 billion tonnes of materials were exported globally in 2010 [2]. The UNEP's recent report [2] suggests that decoupling of material use and environmental impacts is the imperative of modern environmental policy. Material recovery from waste could ease the stress of high dependency on extraction of primary materials. Even in a circular system, we need to be highly dependent on our natural system. A study shows that with a very high aluminium collection and pre-processing rates of 97% each (which is very high compared to current rate of aluminium collection of 49%) and recycling process efficiencies delivering 97% recovery in the smelting process, only 16% of the aluminium remain in the cycle after 10 years [3].

It was found that homes and buildings in developed countries represent 40% of energy consumption, 38% of GHG emissions and 40% of solid waste generation [4]. Although, the contribution of GHG emissions to the atmosphere would be very low from the end-of-life (demolition) waste considering the whole life cycle of a house, recovering resources could be more environmentally beneficial and the recovered materials would usually offset the burdens of extraction of resources. A study conducted by Blanchard and Reppe [5] showed that a typical residential house in the USA contributes only 0.2% of the total global warming potential from waste and mostly contributes during construction phase (7.39%) and use phase (91.9%). However, housing materials contribute around 63% of carbon emission during the construction phase, and thus, reusing and recycling of construction materials would potentially reduce a significant proportion of GHG emissions to the atmosphere.

Demolition generally takes place at the end-of-life phase of a residential building. The traditional demolition of building process involves knockdown of buildings using heaving machineries without caring much about waste materials, as a result, most of the demolition waste is generally sent to landfill. Demolition is an opportunity lost because lots of useable and valuable materials are lost forever due to landfilling. Construction materials prices are rapidly increasing and result in higher housing prices [6]. On the contrary, the deconstruction of buildings, which is "systematic disassembly of buildings in order to maximize recovered materials reuse and recycling", involves carefully taking apart portions of buildings or removing their contents with the primary goal of reuse in mind [7], [8]. Due to the growing awareness on the environmental issues and the global climate change, a systematic deconstruction is seen as an alternative to demolition. In addition, demolition could positively contribute in housing affordability by reusing and recycling construction materials.

This study aims to conceptualize the key challenges and barriers in applying deconstruction to a residential building in New Zealand. The study considers a deconstruction project called "Whole House Reuse" in New Zealand as a case study

Atiq U. Zaman is with the School of Built Environment and Curtin University Sustainability Policy (CUSP) Institute, Curtin University, Western Australia, GPO Box: U1987, WA 6845, Australia (corresponding author, phone: +61 08 9266 9018; fax: +61 8 9266 2711, e-mail: atiq.zaman@curtin.edu.au).

Juliet Arnott is the founder of Whole House Reuse and Rekindle, Christchurch, New Zealand (e-mail: juliet@rekindle.org.nz).

and tries to propose a number of recommendations for the development of comprehensive strategies for deconstruction practices in the Pacific region.

II. Residential Deconstruction and Circular Economy

Deconstruction is not a new phenomenon, in fact; it is a common practice in many developing countries around the world, where the costs of building materials are extremely high and the labour cost is comparatively low. Due to high labour costs, deconstruction is not widely applied in many developed countries. Only a number of studies have been conducted under the form of pilot project and case study analysis to investigate the key challenges and barriers of deconstruction process. A number of studies found that deconstruction costs could be 17–25% higher than demolition costs due to labour cost, disposal cost (tipping fee and transportation), however, it could save approximately 37% for deconstruction over demolition with conservative salvage value (excluding materials storage, inventory, and sales personnel costs) [9]-[11] .

Denhart [11] conducted a study on deconstruction programmes in the USA soon after hurricane Katrina hit in 2005. The study reported on the reclaimed materials from four deconstructed houses. The project redirected around 44 tons of building materials which would enough to build three new buildings. It was found from the study that demolition would cost more around $5.50 per square meter instead of deconstruction ($3.80 per square meter) and even could be profitable ($1.53 per square meter).

Housing deconstruction could have significant influences on circular economy as the fundamental principles of a circular economy are: it preserves and enhances natural capital by controlling finite stocks and balancing renewable resource flows; it optimizes resource yields by circulating products, components and materials in use at the highest utility at all times in both biological and technical cycles; and it fosters system effectiveness by revealing and designing out the negative externalities.

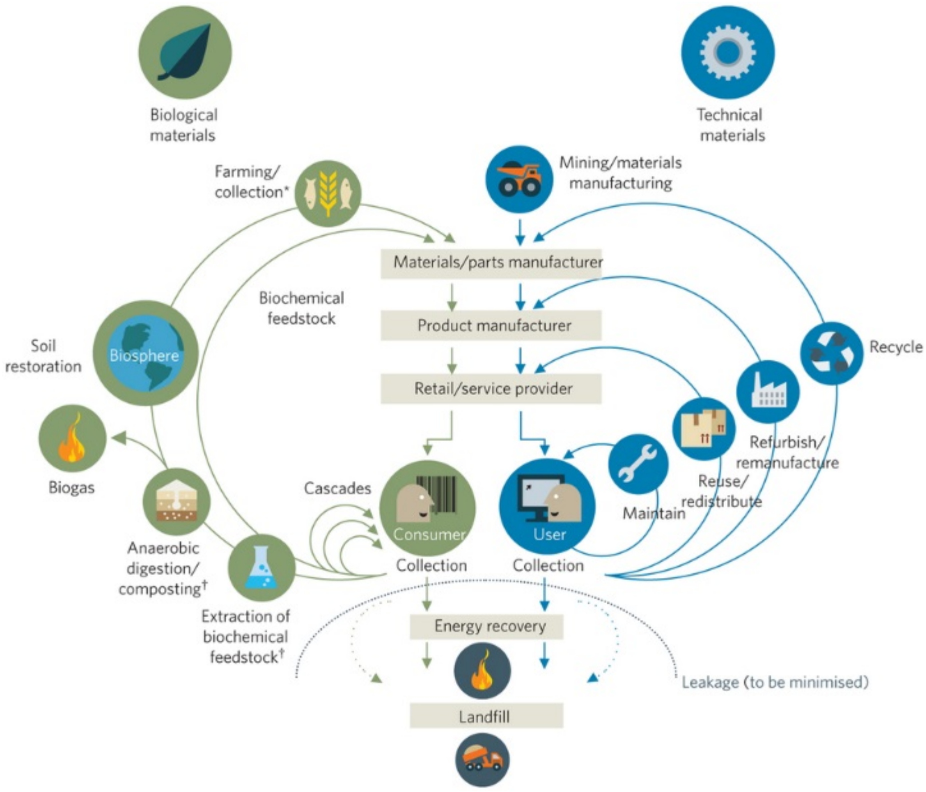

Fig. 1 The circular economy—a restorative industrial system by design [12]

Since, construction industry is one of the main contributors of global resource consumption and environmental pollution with a significantly low rate of resource recovery from waste, deconstruction could potentially be a restorative system that supports circular economy. Fig. 1 shows a schematic diagram of a restorative industrial system where biological and technical materials can be re-circulated within the system for repetitive uses. There is an opportunity to foster circular economy through deconstruction of housing as the process creates employment opportunities, conserves materials, recovers resources and circulates materials within the construction industrial system. It would also be possible to phase out the negative externalities through sustainable design and construction practices so that there is no leakage in system and no waste for landfill.

III. Construction and Demolition (C&D) Waste Management in New Zealand

Each year around 850,000 tonnes of C&D waste is sent to landfills in New Zealand, depending upon the level of building activity (Level, 2014). Although, the New Zealand Waste Strategy-Towards Zero Waste and a Sustainable New Zealand, requires a 50% reduction by weight in construction and demolition waste going to landfills by 2008, it has not yet been enforced as a law and offers no strategies for accomplishing this objective [13]. Flexible and comparative low clean-up rates compared to MSW rates encourage landfill [14]. Fig. 2 (adapted from [15], [16]) shows the key components of C&D waste in New Zealand. The C&D waste in New Zealand mainly consists of timber, metal, concrete, paper, glass and other construction materials.

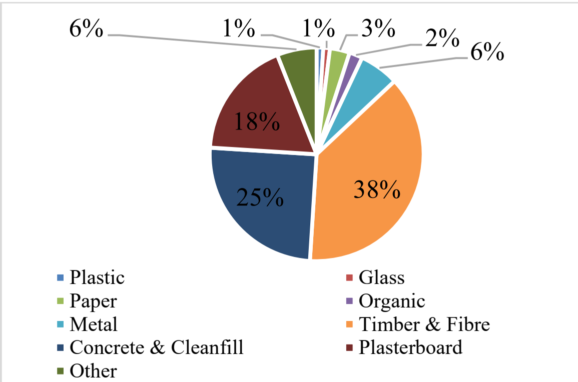

Fig. 2 C&D waste composition in New Zealand

TABLE I
Waste Strategy and Regulations Related to C&D in New Zealand

Legislations/ Policy/Strategy	Brief outlines/relevance	Source
The Resource Management Act 1991	The Resource Management Act controls the environmental impacts of waste facilities such as disposal facilities, recycling plants and clean-fills.	[17]
The Local Government Act 2002	Solid waste collection and disposal is identified as a core service to be considered by a local authority.	[17]
The Climate Change Response Act 2002	This Act also enables the New Zealand Emissions Trading Scheme (ETS).	[17]
The revised New Zealand Waste Strategy 2002	The revised New Zealand Waste Strategy sets out the Government's long-term priorities for waste management and minimisation.	[18]
The Building Act 2004	The Building Act 2004 contains sustainability principles including the efficient and sustainable use of materials and the reduction of waste during the construction process.	[13]
The Waste Management Act 2008	The Waste Management Act 2008 was introduced to encourage waste minimisation and reduce waste disposal by applying a levy on all waste sent to landfills.	[13]

There are many regulatory policies available in New Zealand, which regulate waste recycling and disposal activities. Table I shows the statutory requirement of C&D waste management in New Zealand. Among all relevant regulatory policies, the Resource Management Act (1991), the Climate-Change Response Act (2002), the Building Act (2004) and the Waste Management Act (2008) would be very important in promoting deconstruction in New Zealand.

IV. The Case Study of 'Whole House Reuse' Project

The earthquakes in 2010 and 2011 in Canterbury, New Zealand resulted in much devastation and loss including 10,000 homes being declared fit for demolition and by 2014, around half of the homes within the Residential Red Zone were demolished. Traditional demolition which crushes and removes materials in a relatively quick and tightly scheduled timeframe is the most commonly applied method and homeowners often describe feeling alienated by the demolition process. The Whole House Reuse (WHR) project was initiated and the project celebrates the careful nature of deconstruction and enables products to be made from salvaged resources. The project was seen as an opportunity for examination, transformation and reuse of the often over-looked resources that make up one home. Fig. 3 shows the deconstruction process of the WHR project.

The house was located at 19 Admirals Way, New Brighton, Christchurch and the project was facilitated by Rekindle with the support of the Sustainable Initiatives Fund Trust, Creative Communities and Jamon Construction Ltd. A professional team of salvagers from Silvan Salvage and a team of dedicated volunteers undertook the work of carefully dismantling the home, piece by piece. The recovered items were categorized and catalogued with the details of quantity. Fig. 4 shows some of the catalogued items.

V. Assessment of Recovered Materials

Various construction materials were recovered during the deconstruction process and all materials were catalogued based on the type, volume of the materials and the number of units available. The physical classification and assessment of materials and the potential of materials recovery were determined using the catalogued based on the following criteria presented in Table II. The scores 1-10 were used to rate the materials in the context of reusability, reparability, recyclability and disposal to landfill. A score of 10 means the item could be reused as is without compromising any material and aesthetic value, and a lower score means low efficiency in reusability and recyclability. The study only considers all low hanging fruits which require the lowest level of willingness and efforts to recycle. Thus, the study only considers the materials that scored five or more in the analysis of environmental benefits.

VI. Measuring the Environmental Benefits of Harvested Materials

The environmental benefits of harvested materials were calculated based on energy and associated carbon dioxide emission reduction to the atmosphere. The study used the Inventory of Carbon and Energy (ICE) database to calculate the embodied energy and carbon emission reduction from the recovered materials used in Table III. The calculation used in the ICE database is considered for the geographical context of the United Kingdom. Since there is no similar database for the context of New Zealand, the study assumed the context for United Kingdom and the authors acknowledge that there might be minor errors in the calculation. However, the intention of the article is not to produce a 100% accurate database on the environmental benefits of the deconstruction of an house in New Zealand; rather, the paper initiates the dialogues and discussion on the necessity of conducing a wider application and benefits of deconstruction projects similar to the WHR project.

TABLE II
THE SCORES USED TO CHARACTERIZED CATALOGUED MATERIALS

Scale (1-10)	Description	Interpretation
01	Disposal/landfill	Not suitable for recycling/composting
02	Composting	Suitable for biodegradation
03	Low recyclability	Recycle requires high efforts
04	Medium recyclability	Recycle requires medium efforts
05	High recyclability	Recycle requires low efforts
06	Repair requires high efforts	Substitutes functions with high efforts
07	Repair requires low efforts	Substitutes functions with low efforts
08	Reuse for alternative purposes	Replaces other functionalities
09	Reuse as is	Substitutes similar functions
10	Reuse as is	Substitutes similar functions and aesthetics

TABLE III
THE EMBODIED ENERGY AND CARBON EMISSION REDUCTION FROM C&D MATERIALS [19]

Material types	General material		Virgin material	
	Embodied Energy (MJ/KG)	CO_2e (Kg/Kg)	Embodied Energy (MJ/KG)	CO_2e (Kg/Kg)
Brass	44	2.64	80	4.8
Copper	42	2.71	57	3.81
Aluminium	155	9.16	218	12.79
Lead	25.21	1.67	49	3.37
Stainless Steel	20.1	1.46	35.4	2.89
Bricks	3	0.24	3	0.24
Ceramic	10	0.7	20	1.14
Concrete	0.75	0.107	1	0.15
Glass	11.5	0.59	15	0.91
Masonry	1.1	0.174	1.1	0.174
Melamine	97	4.19	97	4.19
Textile/Fabric	74	3.9	74	3.9
Plastic	80.5	3.31	95.3	3.76
PVC	68.6	3.23	77.2	3.1
Plywood	15	0.45	15	0.45
Timber	10	0.31	16	0.58

VII. RESULTS AND DISCUSSION

A. Characterization of Recovered Materials

The catalogued items were carefully categorised based on physical assessment of the quality of the harvested materials and level of reusability, reparability and recyclability. A total of 480 items were catalogued. Fig. 3 shows the physical rating of various materials. Only 1% of the materials (mainly shelves) were rated as 10, which means that these items and materials could be reused as is without compromising quality, functionality and aesthetics of the materials. Another 1% of the harvested materials were scored as 9 (mainly timber and hardboard materials), which means that these items can be served to meet the purpose of similar quality and functionality. Around 7% of catalogued materials were scored as 8 and most of the materials scored between 5 and 7 (around 70%), which indicated that a significant amount of construction materials (around 79%) can be harvested through the deconstruction process and can be recirculated in the consumption supply chain by reuse, repair and recycle practices.

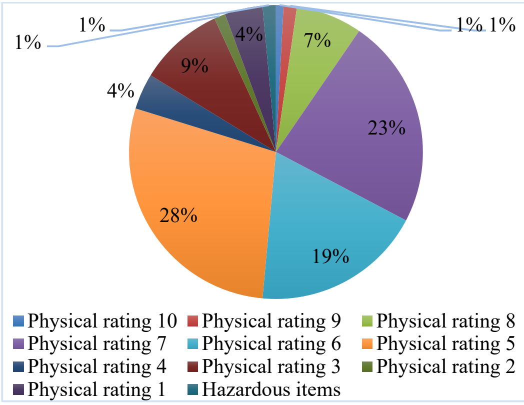

Fig. 3 Physical rating of various harvested materials

A number of studies [20], [21] indicate that successful recycling practices require willingness and efforts. Thus, this study considers all those materials that require low efforts as rated 5 or above, based on the assumption that under current recycling practices these items would be easily recycled instead of disposal to landfill. Fig. 4 shows the various types of materials recovered through deconstruction which has high recycling and material value. A total 12053.5 kilograms of various materials (scored above 5) was recovered, mainly from timber (58.1%), bricks (24.16%) and aluminium (14.16%).

B. Environmental Benefits of Harvested Materials

The environmental benefits of harvesting materials through deconstruction were measured by assessing the embodied energy savings and abatement of carbon emission (CO2e) using the values in Table III. The 'general' material means the item has a pre-selected recycled content which is usually available in the market and the 'virgin' material means the item has been extracted from primary virgin material. Table III shows the embodied energy saving and carbon emission abatement of harvested materials though the WHR project.

Although, timber was the highest contributor (58.2%) compared to general materials, followed by bricks (25%) and aluminium (14.2%), in regard to embodied energy saving, aluminium contributed the most, around 75.37%, followed by timber (19.98%) and bricks (2.57%). A total 350977MJ of embodied energy was potentially saved, and around 18862 kg

(CO2e) of carbon emissions was potentially reduced by recovering materials compared to general material. Compared to virgin materials, around 502,158 MJ of embodied energy was saved and around 27,029 kg (CO2e) of carbon emission was reduced.

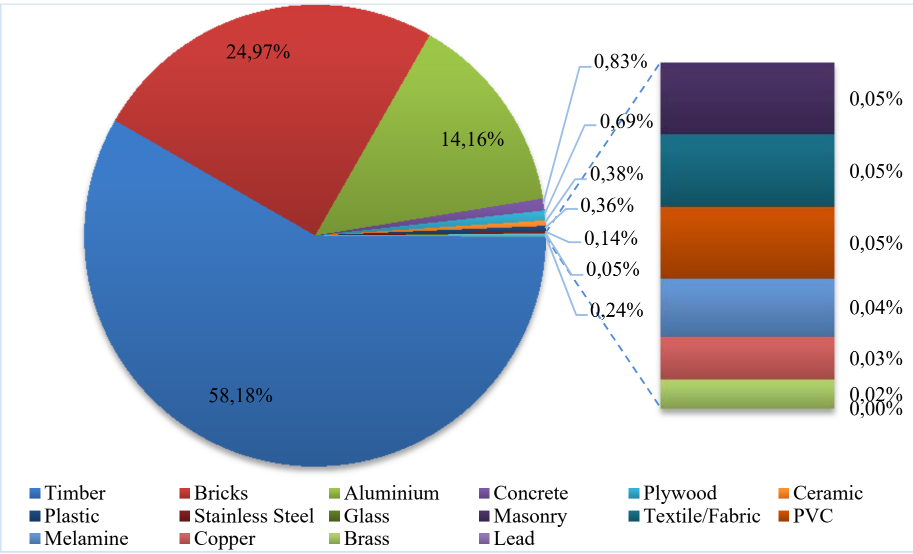

Fig. 4 The composition of recovered materials

Potentially, the WHR project could save around 139,488 kWh of energy, which is equivalent to the annual electricity uses of six households in Christchurch, and the amount of carbon emissions prevented could offset the annual emissions of six passenger cars in New Zealand. Now, using the environmental benefits from the context of the 10,000 homes that were declared fit for demolition in 2011 in Christchurch, a similar deconstruction approach could save around 5,021,580 gigajoules of energy and 270,290 tonnes of carbon emission could be potentially prevented.

New Zealand set national emission reduction targets in July 2015 under the United Nations Framework Convention on Climate Change. New Zealand has set an economy-wide target of 30% below 2005 levels by 2030 (which equates to 11% below 1990 levels). New Zealand also has a longer-term target of reducing emissions to 50% below 1990 levels by 2050 [22]. Without an alternative and innovative approach, it might not be possible to achieve this emission reduction target. Thus, activities similar to the WHR deconstruction project could potentially prevent a significant amount of national carbon emissions, which will assist in achieving national emission reduction goals.

C. New Products from Harvested Materials-a Restorative Industrial System

The WHR project was not only limited to resource recovery from deconstruction, but also created innovative products from the recovered materials. The WHR project was mainly sequenced in three different phases such as the deconstruction of house, creation of innovative products and a public exhibition of the manufactured products from harvested materials. After the completion of the dismantled process, the deconstructed materials were stored for the next phase of project activities. The project involved 282 people, and around 400 objects were produced from the harvested materials in the WHR project. Fig. 5 shows the new products created by various designers.

(a) (b)

Fig. 5 (a) New products from recovered materials (left), designer-Fiona Taylor, (b) long division (right), designer-Emma Byrne (Courtesy: Guy Frederick/Rekindle)

D. The Key Challenges and Lessons Learnt

The project significantly relied on voluntary works of local community and artists. Around 1105.5 hours were spent to produce 52 objects, i.e. an average 21 hours for each object was spent by local artists to create new products from the recovered materials. Though around 122 objects were sold worth NZD $43,425, the project may not be 100% economically viable under current market conditions. However, the project indicates that by minimizing labour cost and involving local communities and artists, the products can have the economic value to foster a wider application of the deconstruction project.

The landfill tax is an important institutional and policy tool to encourage more recycling and less dumping, as it involves costs. Thus, under higher landfill tax, deconstruction activities would be more viable in the context of cost-benefit analysis. Nevertheless, the WHR project was considerably successful in engaging local communities and in some extent preserving the attachments with the house through deconstruction process. Deconstruction does not only provide resource recovery but also rehabilitates the memories and attachment with the materials, space and time. The owners of the case study project have many memories around the house. In a conversation, the owners of the property stated that "that was the place we brought our two boys back after they were born and we had fantastic birthday parties and different moments there". Thus, by harvesting materials and creating new products from the dismantled materials, their emotional attachment to the property was preserved.

The project has significant potential in regards to circular economy as the project involved man power, creative design and recirculation of resources within the products supply chain. However, the project would have been more successful if the existing economic system supported deconstruction activities by considering external costs including environmental pollution costs. The key challenges and barriers that can be faced for such projects are listed as follows:

- Finding appropriate volunteers and their available time and commitment in the deconstruction activities would be crucial for the completion of the similar project.
- Temporary storage of harvested materials was also an issue.
- Ensuring the resale value of new products would also be an important success factor of the deconstruction project.
- Commitment and strategic policy from the local authority on deconstruction would make a significant difference.

Therefore, institutional and economic support is essential to promote circular economy through deconstruction of residential houses. This could be achieved by imposing landfill taxes, supporting local young people and organizations in the deconstruction process and by ensuring a feasible market for the recycling materials as well as the products produced from recovered materials.

VIII. Conclusion

The study presented the deconstruction of a family house called the Whole House Reuse project in Christchurch, New Zealand. The project showed both the challenges and opportunities in deconstruction processes. Although the deconstruction process has a considerable potential for material recovery and environmental benefits, the associated labour costs and resale value of the harvested items would significantly influence the viability of a deconstruction project. The deconstruction may not be completely economically viable under current market conditions, but considering the greater socio-economic aspects and overall environmental benefits in regards to energy savings and abatement of carbon reduction aligned with the national emission reduction targets, the deconstruction process could be an alternative and innovative approach of dismantling old houses in New Zealand instead of demolition. It is expected that an alternative business approach involving local community and commitments from local authorities in ensuring viable economic condition could promote deconstruction activities. Since, the housing and building industry significantly contributes in energy consumption, GHG emission and waste generation, a systematic deconstruction process would reduce a massive environmental burden and promote a greater sustainability worldwide.

Acknowledgement

This article is primarily based on the data of the Whole House Reuse project supported by the Sustainable Initiatives Fund Trust, Creative Communities and Jamon Construction Ltd and the project was instigated and facilitated by Rekindle. The authors declare no conflict of interest with anybody regarding this article. The author uses various photographs related to the Whole House Reuse project with the permission from Rekindle.

References

[1] Schandl, Heinz, 2016. How do we uncouple global development from resource use? The Conversation, published on 21 July 2016, available at https://theconversation.com/how-do-we-uncouple-global-development-from-resource-use-62730.
[2] UNEP, 2016. Global material flows and resource productivity: Assessment Report for the UNEP International Resource Panel, available at http://unep.org/documents/irp/16-00169_LW_GlobalMaterialFlowsUNEReport_FINAL_160701.pdf.
[3] EEA, 2016. Circular economy in Europe: Developing the knowledge base, European Environment Agency, Luxembourg, ISSN 1977-8449.
[4] UNEP-SBCI, 2012. Building Design and Construction: Forging Resource Efficiency and Sustainable Development, United Nations Environment Programme – Sustainable Buildings and Climate Initiative. Available at http://ec.europa.eu/environment/eussd/pdf/Resource%20efficiency%20in%20the%20building%20sector.pdf (Cited on 11.07.2016).
[5] Blanchard, Steven and Reppe, Peter, 1998. Life Cycle Analysis of a Residential Home in Michigan, University of Michigan. Available at http://www.umich.edu/~nppcpub/research/lcahome/homelca3.html (Cited on 11.07.2016).
[6] Shiller, R. J. (2007). Understanding recent trends in house prices and home ownership (No. w13553). National Bureau of Economic Research.
[7] NAHB, 2000. A guide to deconstruction, National Association of Home Builders, Department of Housing and Urban Development, Washington, D.C. available at https://www.huduser.gov/portal//Publications/PDF/decon.pdf (Cited on 11.07.2016).
[8] CIB, 2005. Deconstruction and Materials Reuse –an International Overview, Final Report of Task Group 39 on Deconstruction. Available at http://www.irbnet.de/daten/iconda/CIB1287.pdf (Cited on 11.07.2016).
[9] Dantata, N., Touran, A., & Wang, J. (2005). An analysis of cost and duration for deconstruction and demolition of residential buildings in Massachusetts. Resources, Conservation and Recycling, 44(1), 1-15.
[10] Guy, B., & McLendon, S. (2000). Building deconstruction: reuse and recycling of building materials. Gainesville, FL: Center for Construction and Environment, Report to the Florida Department of Environmental Protection.
[11] Denhart, H. (2010). Deconstructing disaster: Economic and environmental impacts of deconstruction in post-Katrina New Orleans. Resources, Conservation and Recycling, 54(3), 194-204.
[12] EMF, 2015, 'Circular economy overview', Ellen MacArthur Foundation, available at http://www.ellenmacarthurfoundation.org/circular-economy/overview/concept, accessed 29 November 2016.
[13] Level, 2014. Minimising waste, published by Level: Sustainable Building Authority, retrieved on 25 August 2016 available at http://www.level.org.nz/material-use/minimising-waste/.
[14] Storey, John. B. and Pedersen, Maibritt, 2014. Overcoming the barriers to deconstruction and materials reuse in New Zealand, in "Barriers for Deconstruction and Reuse/Recycling of Construction Materials", Shiro Nakajima (edited), CIB Publication 397.
[15] Inglis, n.d. Construction and demolition waste – best practice and cost

saving, Ministry of Environment, available at http://www.cmnzl.co.nz/assets/sm/2260/61/057-INGLISMahara.pdf.

[16] Paterson, C. J. 1997. "Report on a Sorting Trial of Construction Bin Waste as part of Stage 2 of Project C&D". Page 2.

[17] MoE, 2015. Related waste legislation, Ministry of Environment, New Zealand Government, available at http://www.mfe.govt.nz/waste/waste-strategy-and-legislation/related-waste-legislation (accessed on 29 November 2016).

[18] MoE, 2010. The New Zealand Waste Strategy: Reducing harm, improving efficiency, Ministry of Environment, New Zealand Government, available at http://www.mfe.govt.nz/sites/default/files/wastestrategy.pdf (accessed on 29 November 2016).

[19] Hammond, Geoff and Jones, Craig, 2011. Inventory of Carbon and Energy (ICE) Version 2.0. Sustainable Energy Research Team, University of Math, UK. Available at www.carbonsolutions.com/Resources/ICE%20V2.0%20-%20Jan%202011.xls.

[20] Nnorom, I. C., Ohakwe, J., & Osibanjo, O. (2009). Survey of willingness of residents to participate in electronic waste recycling in Nigeria–A case study of mobile phone recycling. Journal of cleaner production, 17(18), 1629-1637.

[21] Schultz, P. W., & Oskamp, S. (1996). Effort as a moderator of the attitude-behavior relationship: General environmental concern and recycling. Social Psychology Quarterly, 375-383.

[22] UNFCCC, 2015. New Zealand's Intended Nationally Determined Contribution, available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/New%20Zealand/1/New%20Zealand%20INDC%202015.pdf.

Atiq U. Zaman is a Lecturer at the School of Built Environment and Curtin University Sustainability Policy (CUSP) Institute, Curtin University, Western Australia. He has more than five years of research experiences in the area of sustainable waste management and assessment. He is an active advocate for zero waste philosophy and activities. Dr. Zaman served as a Guest Editor of the special edition "Sustainable Planning & Technologies" (Vol 1, Issue 3) of Urban Planning open access journal (published by Cogitatio Press). He published four book charters and over 30 peer-reviewed academic journals. He also served as a reviewer of more than 50 peer-reviewed academic journals.

Dr. Zaman's research interests include collaborative consumption, circular economy, urban metabolism, future cities, environmental planning, management and assessment, especially in waste minimization, management and performance evaluation. Dr. Zaman demonstrated his professional experiences in cross-disciplinary working areas, including environmental engineering, environmental compliance, auditing, monitoring, health and safety and cleaner production. He has worked with a number of international organizations such as the United Nations and H&M.

Juliet Arnott is an artist and occupational therapist, and the founder of Whole House Reuse and Rekindle. Her work focuses on resourcefulness and craft as crucial, yet often overlooked capabilities of humankind, necessary for wellbeing of both people and planet. Juliet's work often involves inviting people to become makers to transform under-valued material resources, and in doing so to value their own inner resources. She regards wastefulness as missed opportunities for the beneficial practice of resourcefulness. Juliet lives simply in Ōtautahi Christchurch, Aotearoa New Zealand.